AN ATTEMPT TO DETERMINE THE NORMAL RANGE OF ACCOMMODATION AT VARIOUS AGES — BEING A REVISION OF DONDERS' EXPERIMENTS.

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Donders in his classic experiments on the accommodation determined the absolute near point in a series of subjects under 45, who were assumed to be emmetropic, and in a series of subjects over 45, who, for the most part hypermetropic at the time of examination, were assumed to have been emmetropic earlier in life. Since, in the absence of cycloplegic tests, no person below the age of 45 can be pronounced to be emmetropic — since, in fact, we know that 1 or 2 D of hypermetropia may remain latent up to and even beyond that age — both of Donders' assumptions must be regarded as at least open to criticism.* However this may be, what we wish to know as clinicians is not the way in which the absolute near point recedes in an eye which began by being emmetropic and afterwards became more or less hypermetropic, but rather the absolute range of accommodation at each age and the limits within which this range may vary. To ascertain this in a sufficiently large number of cases, a series of experiments have been made by Dr. J. B. Thomas and myself. In carrying them out we first rendered each patient absolutely emmetropic by glasses; then ascertained his near point with this correction. This, of course, gave the range directly. The values thus obtained for the range were

* Especially the second. In speaking of the hypermetropia which he believes to develop late in life and cause a recession of the far point, he says: "I have not infrequently met with this in persons of sixty years of age, who in their youth probably exhibited no H. whatever. This was inferred when they did not before the forty-fifth year of their life need spectacles in the evening for close work." With our present knowledge this inference would certainly be unwarranted.

then plotted on a diagram like that used by Donders. Under the conditions employed the diagram assumes the form shown in Fig. 1. That is, the line, CC, denoting the far point at different ages coincides everywhere with the zero or base line, instead of falling below it at the age of 45; and after the age of 50, the line, AA, denoting the near point, instead of approaching the base line, runs nearly parallel with it, i. e., is almost horizontal.

In pursuing the plan above outlined close attention had to be paid to the following points:—

1. The subject must be made really emmetropic, i. e., his refraction must be wholly and accurately corrected. In order to effect this, the refraction was carefully determined in every one of our cases, and a cycloplegic was used in all under 48 and in some over that age. Especial care was taken to determine the astigmatism accurately, to within 0.25 or even 0.12 D.

2. The subject's vision must be such that he is capable of making the fine distinctions required in the test. That is, he must have clear and good vision with his glasses. Hence we were obliged to reject cases of irregular astigmatism, of high astigmatism even when corrected, of high myopia, of amblyopia from any cause but especially amblyopia associated with any defect in central vision, of poor vision from corneal or lenticular opacities, etc. Subjects thus affected, can not discriminate between the blurring due to accommodative failure and the blurring due to their naturally defective vision.

3. When the near point is not further than 50 cm. nor closer than 10 cm., it is best to apply the full correction, without addition or subtraction, and then determine the near point. This, of course, gives the range of accommodation directly.

4. When the near point is closer than 10 cm., a slight error in determining its position will involve an error of several D. in the estimation of the range of accommodation. In such cases it is well first to make the test as above described, i. e., with the full correction alone, and then with the latter combined with a—4

or a — 5 D. spherical, so as to carry the far point out beyond 10 cm. It must be noted, however, that tests made in this latter way — either because of the diminution in the apparent size of the test-object or because of the sudden strain put upon the accommodation — usually give an underestimate of the patient's accommodative power. Thus a patient to whose distance correction we have added — 5 D. may show a near point of 13 cm. corresponding to 7 D. of accommodation and indicating a total range of only 12 D., and yet when otherwise tested he may show an actual total range of 14 or 15 D.

5. In subjects whose near point is beyond 50 cm., a suitable convex glass must be added to their full correction to bring the near point within measurable distance. Such convex addition should be as small as possible. For, a strong convex glass, probably on account of the magnification that it produces, sometimes brings the near point closer than it should be theoretically. Thus, a patient with + 3.50 D. added to his distance correction may have a near point of 17 cm. indicating an accommodation of 6 D., or a net range of 2.50 D., and yet when we test him in other ways we find that his true range is not over 1.50 D. In general, then, when we make tests of this kind, the auxiliary convex glass is made just strong enough to bring the near point to 50 cm. or somewhat less.

6. The subject's accommodative power, or rather his will and ability to exercise it, vary a good deal according to circumstances, especially in young subjects. Hence, in order to establish the actual accommodative power, repeated tests are necessary even in the same subject. Some of our cases afforded a striking example of this variability. Thus, Lena B. when tested at the age of 15 showed an accommodation of 8.50 D., which a year later rose to 9.50 D. So Dr. H. at the age of 30, had a range of about 5 D., and some months later a range of 7 D. In each case the first measurement surely meant a range which was not only below the average for the age but also below the average of the individual.

Regard to this point, i. e., to the necessity of making repeated observations in a case before deciding as to its accommodative range, has forced us to exclude a number of cases in which we were able to make the test but once under proper conditions.

7. We must always be on the lookout for erroneous or careless observation on the part of the patient. Careful attention to details and careful explanation of what he is required to notice will obviate this cause of error. Particularly must we urge young subjects to put forth all their efforts and strain as hard as they can, so as to focus down upon the test-object at the closest possible point. Again they must be careful to notice the first sign of blurring or doubling of the test-object — indicating the point where this begins to occur and not the point where the object becomes entirely confused.

8. Last, and by no means least, our method must be such as to afford the most accurate results. Here we must consider:—

(*a*) The character of the test-object. Donders used fine print in order to ascertain the near point. This, however, for most people does not afford a very accurate test. With me, for example, it gives a near point corresponding to a range nearly 1 D. greater than the true one. After trying a number of objects — dots in pairs and groups, parallel lines, simple geometrical figures, etc., we have concluded that the best test-object for practical purposes is a simple engraved line 0.2 mm. thick and 3 mm. long. This when brought within the near point blurs slightly and then doubles. If the subject's attention is called to this fact and he is cautioned to indicate the very nearest point at which the line is still clear and sharp, a good estimate of the true punctum proximum will be got.

As Hess points out, Scheiner's test gives a more accurate means of determining the absolute near point, but while the test is suitable for physiological experiments, repeated trials have convinced us that it is not available for clinical purposes. What we require of a test of this sort, for it to be practically useful, is that it shall be applicable to all sorts of subjects, even the un-

trained and unintelligent. If it does this and if, furthermore, when used under proper conditions, it gives the near point with fair accuracy, it will be much better for our purposes than a test which is difficult of application but scientifically more precise.

So far as accuracy is concerned, tests on myself seem to show that the fine line if made slender enough and sharp enough gives almost precisely the same results as Scheiner's test.

(*b*) The illumination. This is a matter of great importance. The light should come from behind over the right shoulder when the right eye is tested and over the left shoulder when the left eye is tested. Furthermore, care should be taken that there is no shadow on the card and no dazzling reflections or confusing lights beyond it or alongside. For this reason when the test is made with Prince's rule, the latter should be held with its broad side vertical and not horizontal, as in the latter position the graduations on the rule and the glare from its surface are apt to distract the patient's attention or cause confusion.

(*c*) The starting point of the measurement. Generally the measurements are made from the anterior principal point of the eye. For practical purposes, this is taken to be equivalent to the anterior surface of the cornea — the small error of less than 2 mm. being disregarded. I, however, in making my estimates have preferred to reckon from the anterior focus of the eye, i. e. from a point 13 mm. in front of the cornea. My main reason for doing so is that this is the point at which we place the convex glass that we use to measure the accommodative power and to replace the latter when absent. Thus, when we speak of a deficiency of accommodative power of 6 D, we mean a deficiency that will be replaced by a lens of that strength placed at the anterior focus (not at the anterior principal point) of the eye.

The difference between the results obtained by the two methods of measurement is shown in the following table computed from the figures obtained by Donders:

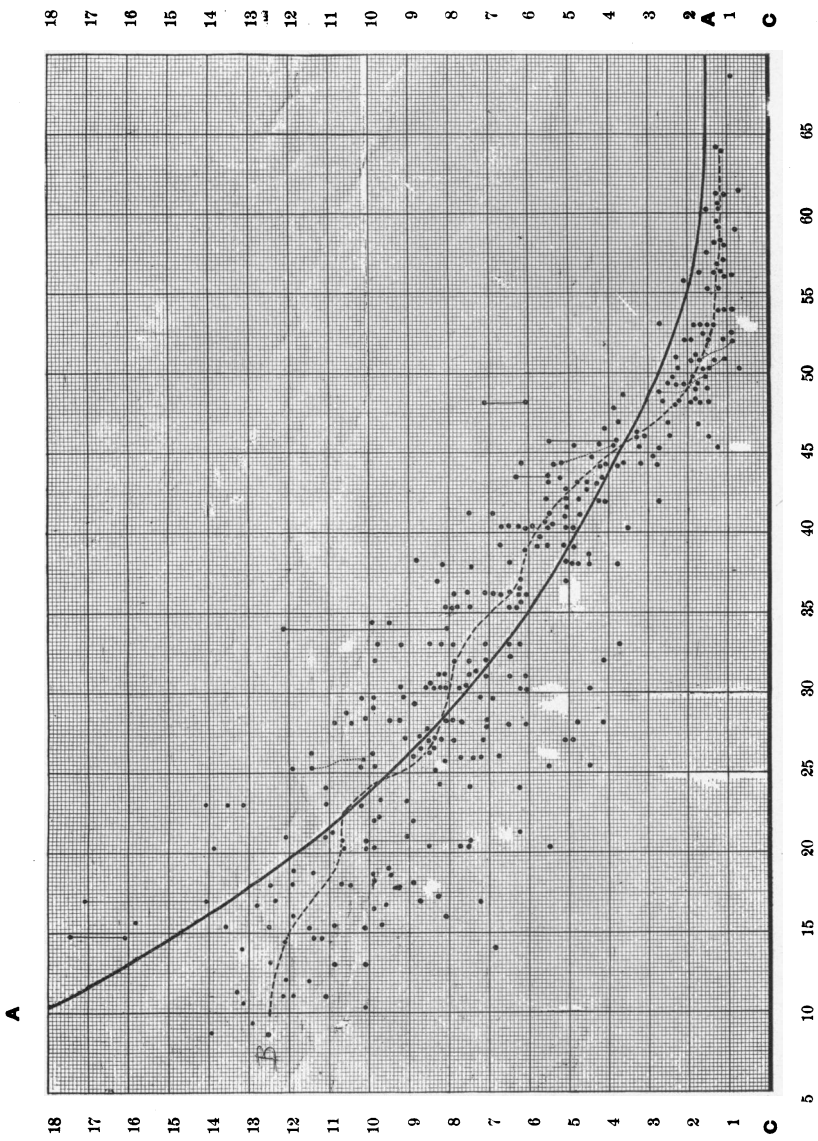

FIG. 1.

RANGE OF ACCOMMODATION AT DIFFERENT AGES.

Each dot denotes the range found in a certain case at a certain age — the patient being rendered strictly emmetropic by glasses. A marked and constant difference between the accommodation of the two eyes in the same subject is indicated by a pair of dots connected by a vertical unbroken line — the accommodation in the right eye being shown by one dot and that in the left by the other. Dots connected by a fine dotted oblique line denote different findings at different ages in the same case. The near point was measured always from the anterior focus of the eye. The heavy black curved line, AA, is Donders' curve modified so as to conform to this measurement and to represent not the absolute near point but the absolute range of accommodation at each age. The heavy broken line, BB, shows the average curve as we found it in 390 cases.

Age.	Range computed on the assumption that the glass equivalent to the amount of accommodation is placed at the anterior principal point of the eye. (1. 7. mm. behind the cornea.)	Range computed on the assumption that the glass equivalent to the amount of accommodation is placed at the anterior focus of the eye (13 mm. in front of the cornea.)
10	14	18
15	12	15
20	10	11.8
25	8.5	9.7
30	7.0	7.8
35	5.5	6.0
40	4.5	4.8
45	3.5	3.7
50	2.5	2.6
55	2.0	2.0
60	1.5	1.5
65	1.5	1.5
70	1.5	1.5

It will be seen that when the near point is close to the eye, the differences are considerable (3 or 4 D). This is also obvious from our Fig. 1, in which the black curved line AA represents Donders' presbyopic curve when plotted according to the method of measurement here advised. It will be seen that the curve at its beginning rises much higher than the curve as ordinarily depicted.*

(*d*) Uniformity in the methods and the test-objects employed. If our results are to be comparable with each other, we must in every case employ the same sort of test-object, take the same precautions as regards illumination and other conditions, and make our measurements from the same point of reference.

Having regard to these requirements, Dr. Thomas and I have examined a large number of cases, of which nearly 400 have proved available for tabulation. This is about three times the number of cases that Donders used to base his results on.

Many as the cases are, they are yet too few for a final analysis, and the conclusions based on them must be regarded as tentative only. Some of these conclusions are as follows:

1. The findings as regards the absolute range of accommodation and consequently the shape of the presbyopic curve differ

* And for the reason stated before is much flatter at its end.

somewhat from those got by Donders (see lines AA and BB in Fig. 1).

2. As a particular exception, the accommodation in childhood and youth seems to be not so high as he stated. I have rarely found a range much above 14 D (11 D if the near point is measured from the cornea) in children between 8 and 13.

3. The range does not apparently seem to diminish much between the ages of 10 and 15. It is even possible that it may rise, and that the maximum accommodation is found somewhere about the age of 16 or 18. But many more observations than we have would be required to prove or disprove this.

4. The accommodation does not decrease year after year by any steady sweep, but at some periods of life seems to remain about the same for years together and then descend rapidly.

5. Two periods of apparent stasis are those from 25 to 30 and again from 35 to 40. To make sure of this point, however, many more observations would be required than we have in hand.

6. Much more certainly demonstrated seems to be the decided and rather abrupt plunge that begins at the age of 40 and continues uninterrupted to the age of 51. The accommodation during these eleven years falls from 5.9 to 1.50 D, a drop of 4.4 D, while in the preceding eleven years it falls 3.4 D.

7. After 51 the accommodation remains nearly constant, diminishing not more than 0.50 D in ten years.

8. The average, minimum, and mean ranges that we have found at the different ages (excluding the cases that were probably distinctly sub-normal) are as follows:—

Age.	Mean	RANGE. Low.	High.	Donders' Average.
10	14.0	10.0	16.5	18.0
15	13.0	9.7	16.0	15.0
20	10.7	7.5	14.0	11.8
25	9.6	8.2	12.0	9.7
30	8.8	6.3	10.4	7.8
35	7.0	6.5	8.0	6.0
40	5.9	4.9	6.7	4.8
45	3.8	1.3	5.0	3.7
50	1.8	0.7	2.3	2.6
55	1.3	1.2	2.0	2.0
60	1.2	1.2	1.5	1.5

9. Owing to the variations shown by the same case from time to time, a single determination of the accommodative power is of little value. This is particularly so if the value found is subnormal or if the proper conditions of examination have not been fulfilled.

10. Some peculiarities may be mentioned.

(*a*) The highest range noted (17 D) was found in a patient of 17.

(*b*) Three at the age of 23 had an accommodation of 13 to 14 D.

(*c*) One patient of 48 had an accommodation of 6 D in one eye and 7 D in the other. This was associated with a marked (probably spastic) miosis, paresis of the abducens, and some other symptoms indicative of brain irritation. I regarded the condition as a true spasm of accommodation. It is not unlikely, however, that it was an instance of the spurious accommodation, which Hess regards as so frequently in presbyopes. That is, the patient on account of her miosis was able to see objects at close range without really accommodating for them.

11. Cases of unequal accommodative power — not meaning by this cases in which the two eyes accommodated unequally when working together but cases in which the maximum power of one eye was persistently higher than that of its fellow when tested by itself, were not very uncommon.

12. Corrected myopes frequently showed a surprisingly high power of accommodation. Thus a patient of 21 with a myopia of 3 D had a range of 12 D, a patient of 23 with a myopia of 3.50 D a range of 14 D, and a patient of 25 with a myopia of 7 D a range of 11 D, and a patient of 18 with a myopia of 13 D a range of 12 D.